

# Maritime Energy Systems related research activities at NUS

## Maritime Institute @ NUS

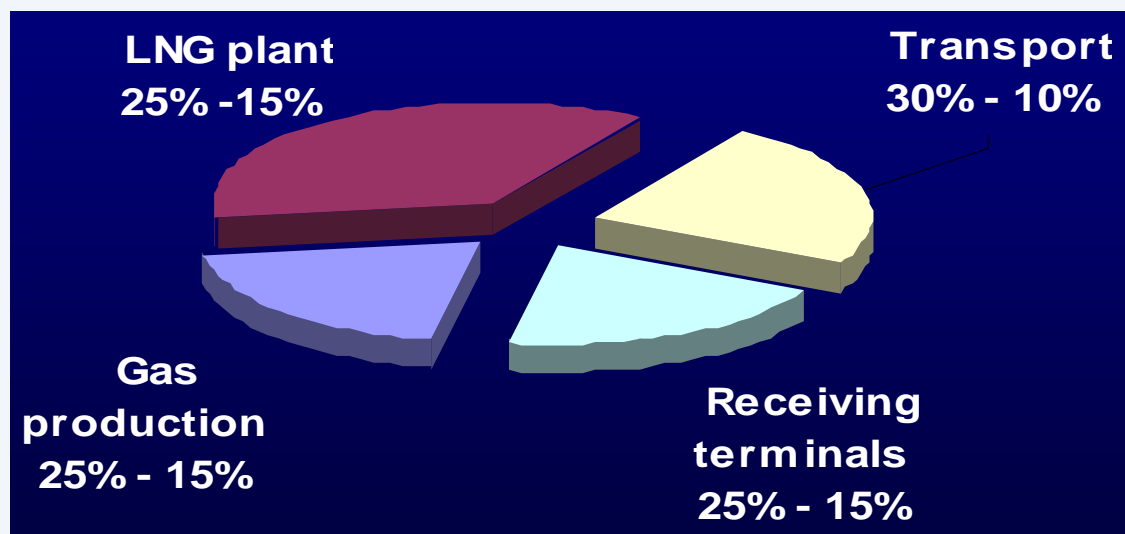
# Presentation Outline

- 1. Presentation on LNG and Biofuels**
- 2. Presentation on Integrated Power Electric Propulsion & Energy Management Systems**
- 3. Q&A**

# LNG & Biofuels



# LNG Value Chain Costs



EXPLORATION & PRODUCTION	LIQUEFACTION	SHIPPING	REGASIFICATION & STORAGE
\$0.5-\$1.0/MMBtu	\$0.8-\$1.20/MMBtu	\$0.4-\$1.0/MMBtu	\$0.3-\$0.5/MMBtu

## Past/Current Research Projects

- **Methane storage & transport**
- **Transport & logistics**
- **Fuels & LNG bunkering**
  - Market potential for LNG in Singapore
    - ✓ IA Karimi, KM Teo, BC Khoo, Shell, Rolls-Royce
    - ✓ SMI/MPA, Shell, Rolls-Royce
- **Energy efficiency**
- **Carbon capture & emissions**



# Methane Storage & Transport

Expertise / Project	Principal Researchers	Goal/ Motivation	Collaborators /Funding
Transport as ANG or adsorbed natural gas	KC Ng (ME) YS Choo (CEE) BC Khoo (ME) WS Loh (ME)	Short sea and small carriers for distribution & power generation	MPA, SLNG, gas companies
Methane hydrates for transport and production	TS Tan (CEE) A Palmer (ME) P Linga (ChE) S Adams (MSE)	Carbon storage and methane resource	A*STAR, MPA, CORE
Well placement / Reservoir modeling	IA Karimi (ChE) KM Teo (ISE)	Reduce drilling costs & increase success rate	RPI Energy, Sharif Uni

# Transport & Logistics

Expertise / Project	Principal Researchers	Goal/ Motivation	Collaborators /Funding
Logistics network optimization	IA Karimi (ChE) KM Teo (ISE)	Supply/ Distribution	Shell, Rolls-Royce,
Sloshing and ship stability	BC Khoo (ME)	Modeling & simulation	MPA, Qatar Uni, QNRF
Ship operations planning, & inventory management	IA Karimi (ChE)	Chemical parcel tankers	MPA, NTNU, BMT Asia, GBLT, Odfjel, Stolt-Nielson
Integrated green and efficient shipping	Ng Szu Hui (ISE) Chang Che Sau (ECE)	Fuel management of liner shipping	APL, NOL
Understanding vessel movements & interactions	Chang Che Sau (ECE)	Naval decongestion and safety	

# Fuels & LNG Bunkering

Expertise / Project	Principal Researchers	Goal/ Motivation	Collaborators /Funding
Next generation dual-fuel internal combustion engines	WM Yang (ME)	Reduce emissions & increase efficiency	
Bunkering operations	IA Karimi (ChE) KM Teo (ISE)	Infrastructure & market potential	Shell, Rolls-Royce, MPA, SMI
Biodesulfurization of bunker fuels	IA Karimi (ChE)	Deep desulfurization	IIT (USA)
Fuel efficiency & engine combustion	IA Karimi (ChE) M Saeys (ChE)		Cambridge, NRF



# Energy Efficiency

Expertise / Project	Principal Researchers	Goal/ Motivation	Collaborators /Funding
Process intensification	GP Rangaiah (ChE)	Reduce footprint, weight	
Energy integration & process optimization (Refrigeration systems)	IA Karimi (ChE) GP Rangaiah (ChE)	Reduce fuel usage	QatarGas, Qatar Uni, SLNG, A1 Process Associates, KFUPM
Waste heat recovery systems	YK Koh (ME)	Thermo-electric designs	
Waste heat driven adsorption desalination & cooling	KC Ng (ME)	Conserve energy	Singapore, Poland, Saudi Arabia
Boil-off reduction/ fuel gas networks	IA Karimi (ChE)	Reduce flaring	Qatargas, UT Austin (USA)

# Carbon Capture & Emissions

Expertise / Project	Principal Researchers	Goal/ Motivation	Collaborators /Funding
Adsorption-based carbon capture	S Farooq (ChE) IA Karimi (ChE) J Jiang (ChE)	Reduce footprint & energy penalty	ICES, A*STAR
Separation technologies	S Farooq (ChE) TS Chung (ChE) IA Karimi (ChE)	Reduce SO <sub>x</sub> , Nox, & CO <sub>2</sub>	KOMTech
Fuel consumption & carbon emissions in Singapore port	S Bayen (CEE)	Gather data and study emission patterns	



# Biofuels



# Bioenergy

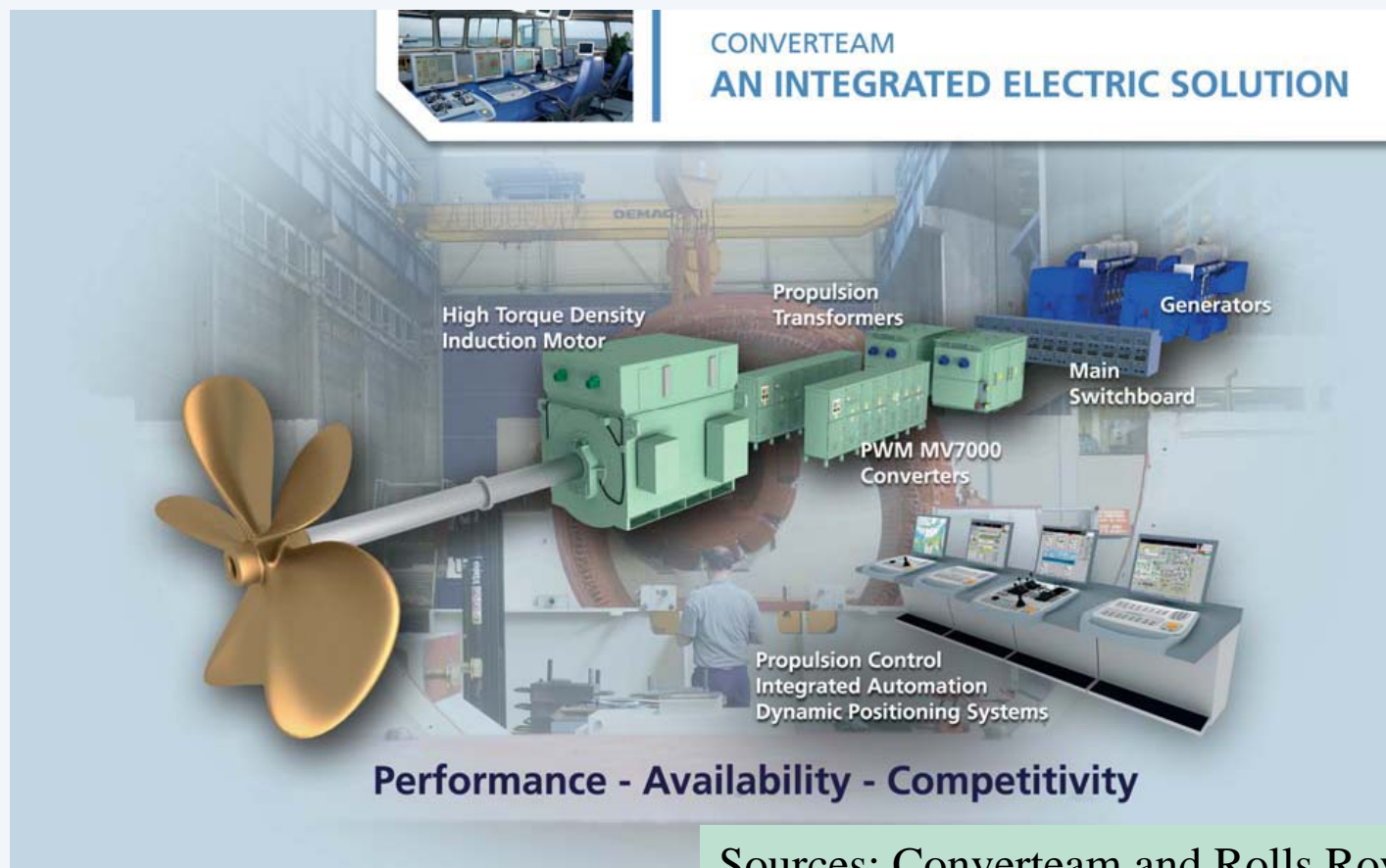
Expertise / Project	Principal Researchers	Goal/ Motivation	Collaborators /Funding
Cellulosic / Lignocellulosic biomass conversion	JZ He (CEE) IA Karimi (ChE) Z Zhou (CEE) DY Lee (ChE)	Reduce carbon emissions; alternative feed sources	Refineries, SPC, Caltex, A*STAR, ICES, Wilmar
Algae bioenergy (Photobio reactor, systems biology, anaerobic digestion)	KC Loh (ChE) YW Tong (ChE) L Yung (ChE) DY Lee (ChE)	3 <sup>rd</sup> generation biofuels, non-food crop, CO2 sequestration	Metax Engg, Sembcorp, Oiltek, Aquarius systems, Keck Seng, Keppel Seghers
Catalytic trans-esterification of algae oil (developing acid-base catalysts)	S Kawi (ChE) K Hidajat (ChE) D Leong (ChE)	Synthetic diesel	Sime Darby, Ecogreen oleochemicals

# Bioenergy

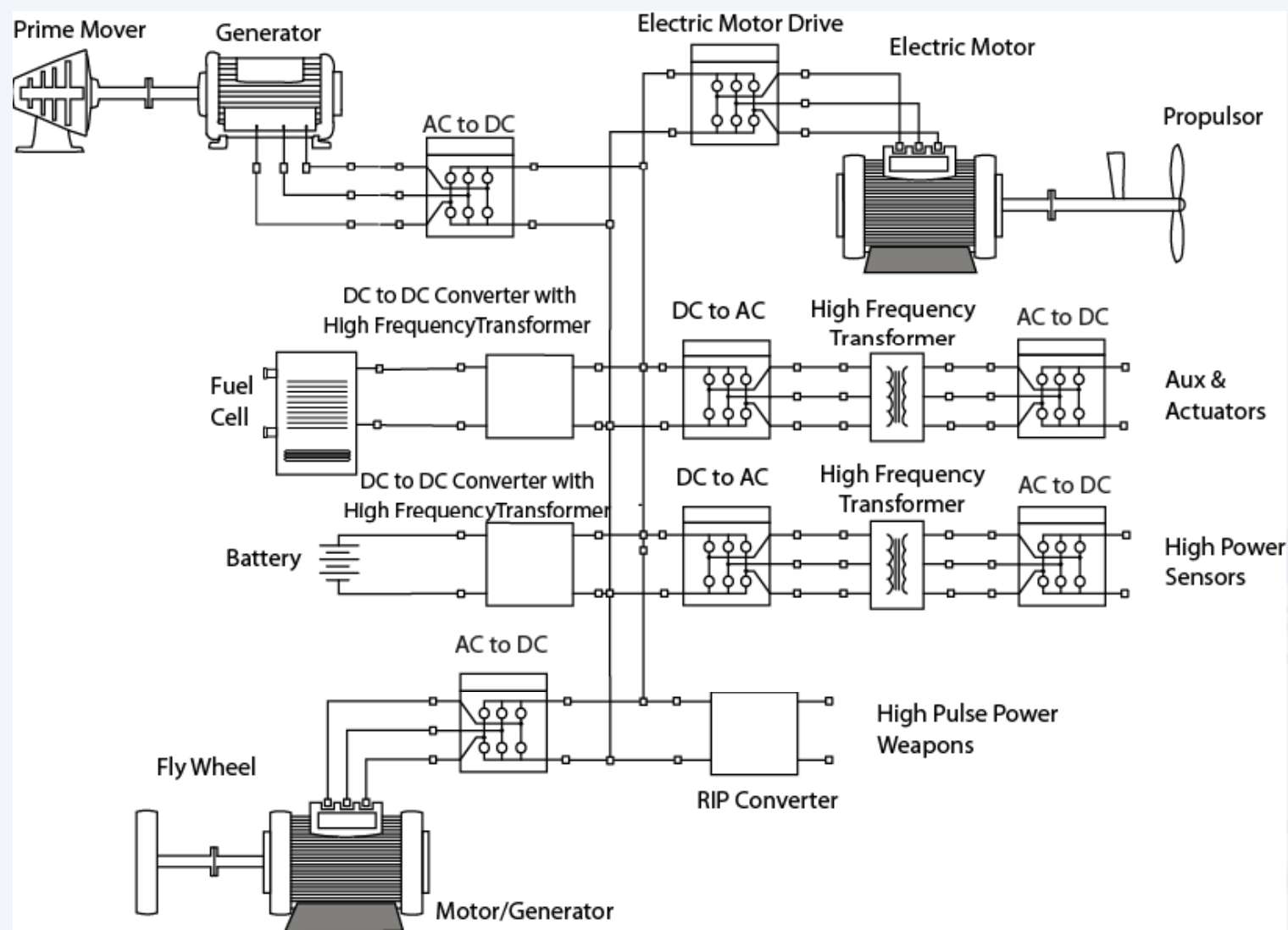
Expertise / Project	Principal Researchers	Goal/ Motivation	Collaborators /Funding
Biotransformation for biodiesel (High throughput screening for biocatalysts, synthetic biology)	Z Li (CEE) IA Karimi (ChE) DY Lee (ChE)	Strain improvement	Alpha Biofuels
Maritime algae wastewater treatment	M Quah (ChE)	CO2 sequestration	Jonathan Trent (NASA)

# Integrated Power & Electric Propulsion





- **Integrated power and propulsion system can**
  - ✓ Reduce fuel consumption by almost 50%
  - ✓ Reduction in gas emissions, CO<sub>2</sub> and NO<sub>x</sub> by 50%



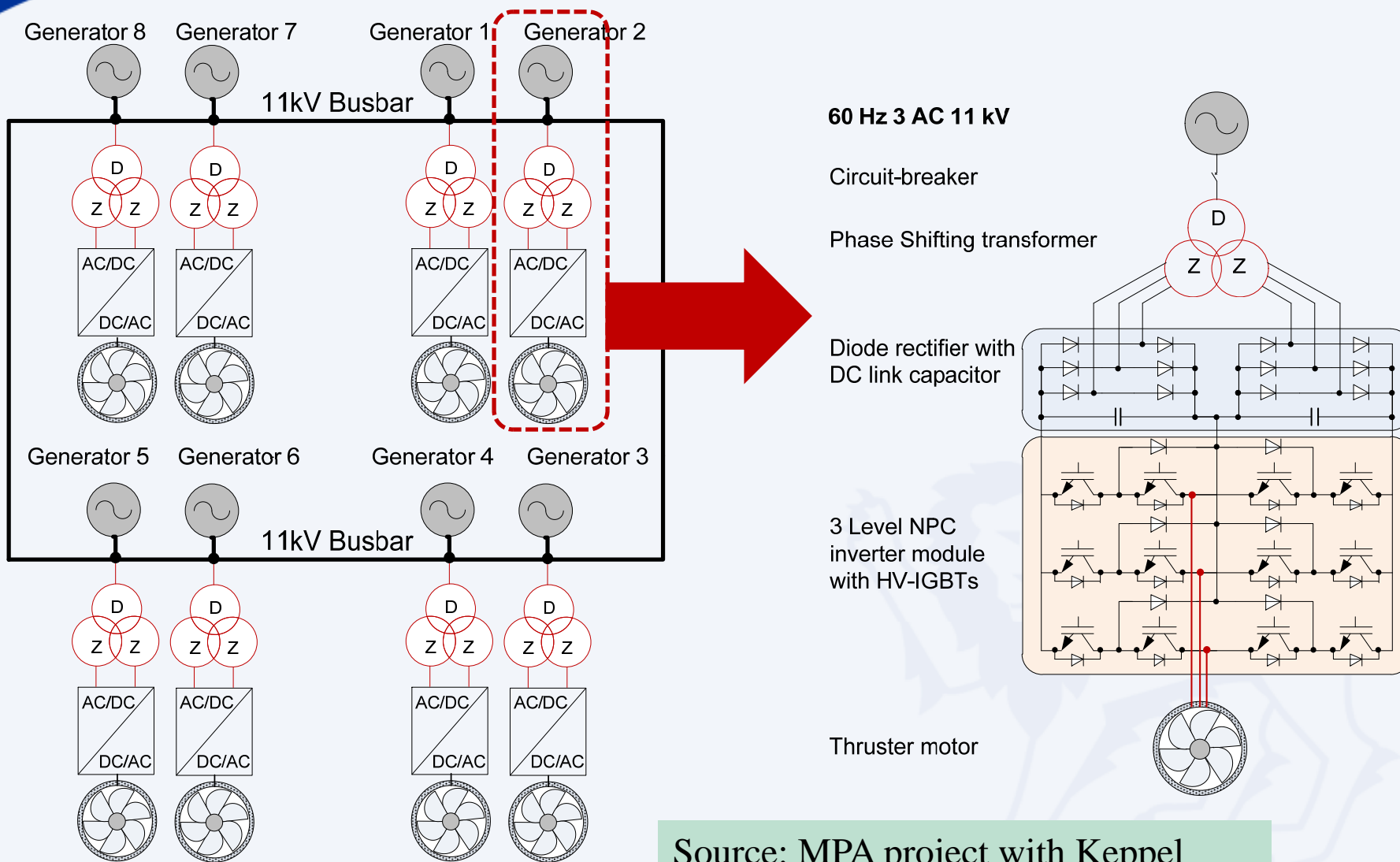
Source: IEEE PCCI Paper by Terry Ericson, 2009, IPSS: A DC Distribution Concept Derived From the DC Link of a AC to AC Motor Controller



## Past/Current Research Projects

- **Electrification of transport sector**
- **Smart-grid**
- **Power Electronics and Motor Drive Systems**
- **Energy efficiency**
- **High-power Semiconductor Devices**
  - Industrial collaboration
    - ✓ Sanjib K. Panda, Keppel FELS, Rolls-Royce, Infineon
    - ✓ Chang Che Sau, Keppel FELS,
    - ✓ YC Liang, A\*STAR (IME)
    - ✓ SMI/MPA, A\*STAR (EPGC, ICCS, IME, SimTech, I2R), JTC, URA,

# Electric Propulsion

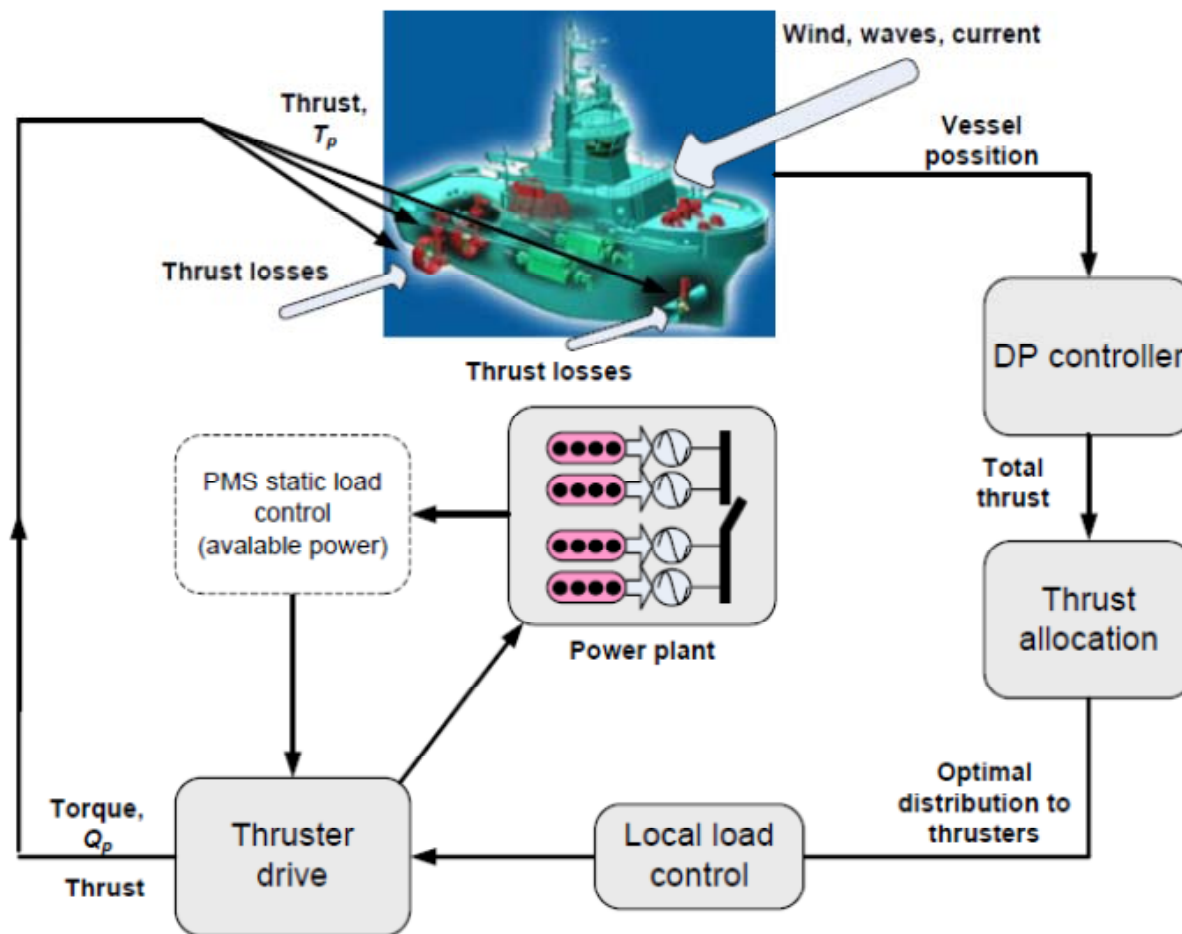


Source: MPA project with Keppel

## Electric Propulsion (cntd.)

- Shunt Active Filter to eliminate current harmonics at bus bar to ensure lowest possible VTHD under unbalanced load as well as generalized grid voltage conditions.
- Replacing front end diode-bridge-rectifier with Active PWM Rectifier
  - Optimized Switching Frequency operation of PWM rectifier with Multi-level topology.
  - Implementation with High Power IGBTs with medium switching frequency.
- Implementation of the thruster motor drive using Load Commutated Inverter fed Synchronous Motor Drive to ensure high dynamic performance at reduced cost.
- Applications of wide band-gap high-power semiconductor devices SiC or GaN or Diamond for high switching frequency operation of power electronic converters.
  - Improved current waveforms with lower THD and compact size

# Integrated Power Management System



Marine Control Structure

# Integrated Power Management System

- Optimal scheduling of the generators to reduce the fuel consumption in maritime vessels by about 5%.
- Energy Efficient Thrust Allocation algorithm for maritime vessels with energy savings of about 40%.
  - Ensuring less wear and tear of thruster motor;
  - Enhanced Dynamic Performance of the drive, because, the thrusters operate in the efficient region (at higher load);
  - Simpler  $v/f$  control can be used to control the induction motor; and
  - No need of additional hardware integration. The proposed approach can be integrated in the existing system by changing the DP software.

# Condition Monitoring & Predictive Maintenance of Marine Power Plant



# Completed Research Project

## Predictive Maintenance and Condition Monitoring of Marine Power Plant, Collaborators: MPA & APL

- ✓ Chang Che Sau, ECE
- ✓ Tan Woei Wan, ECE

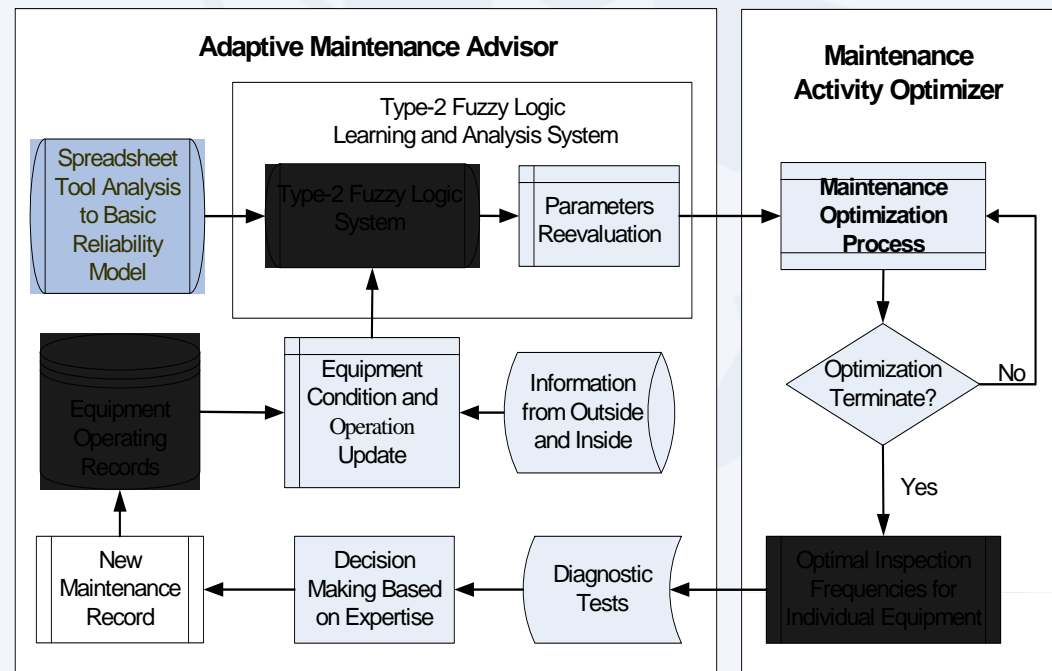


# Predictive Maintenance and Condition Monitoring of Marine Power Plant (1/4)

## Objectives:

- *Optimisation of Adaptive Fuzzy Maintenance Advisor for offshore power system according to operation uncertainties and condition updates*
- *Implementation of fault detection algorithms for electric motors and wind - power generators*

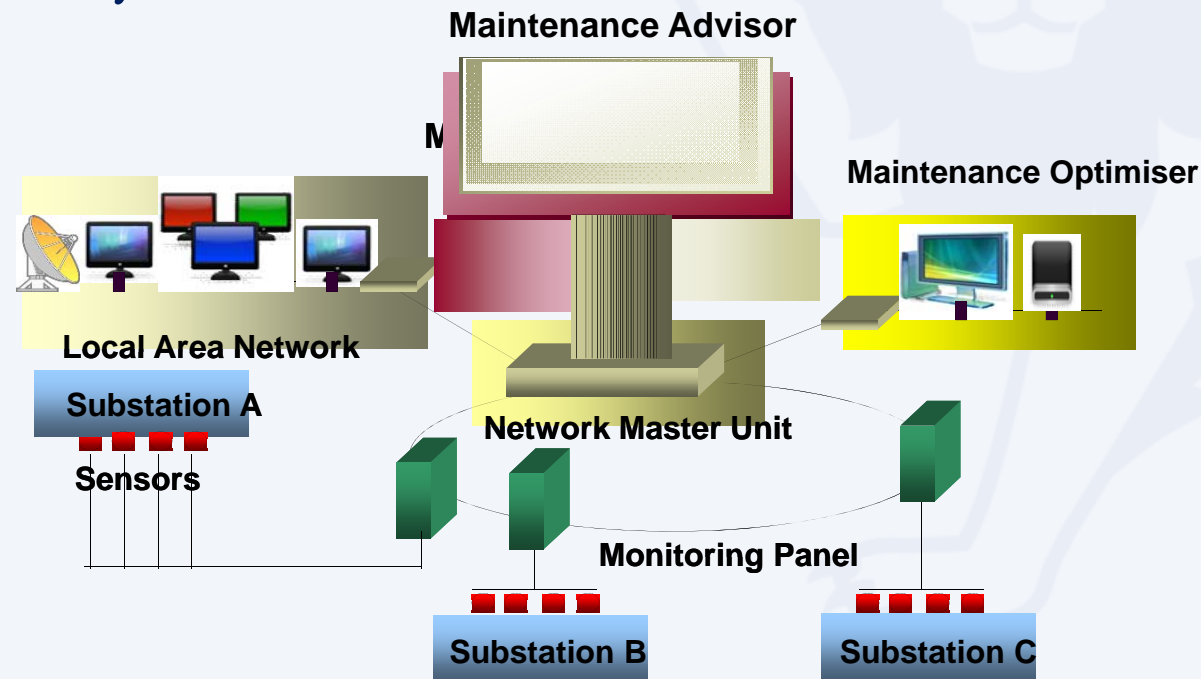
## Overall Architecture:





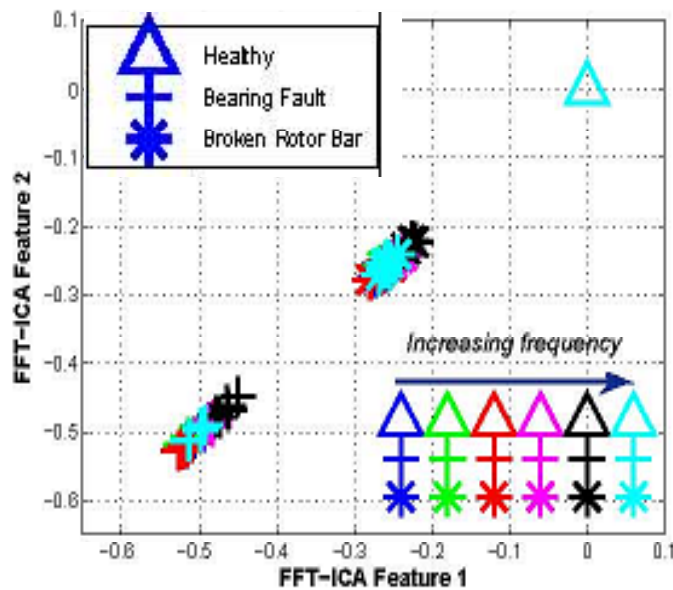
# Predictive Maintenance and Condition Monitoring of Marine Power Plant (2/4)

## Overall Layout:

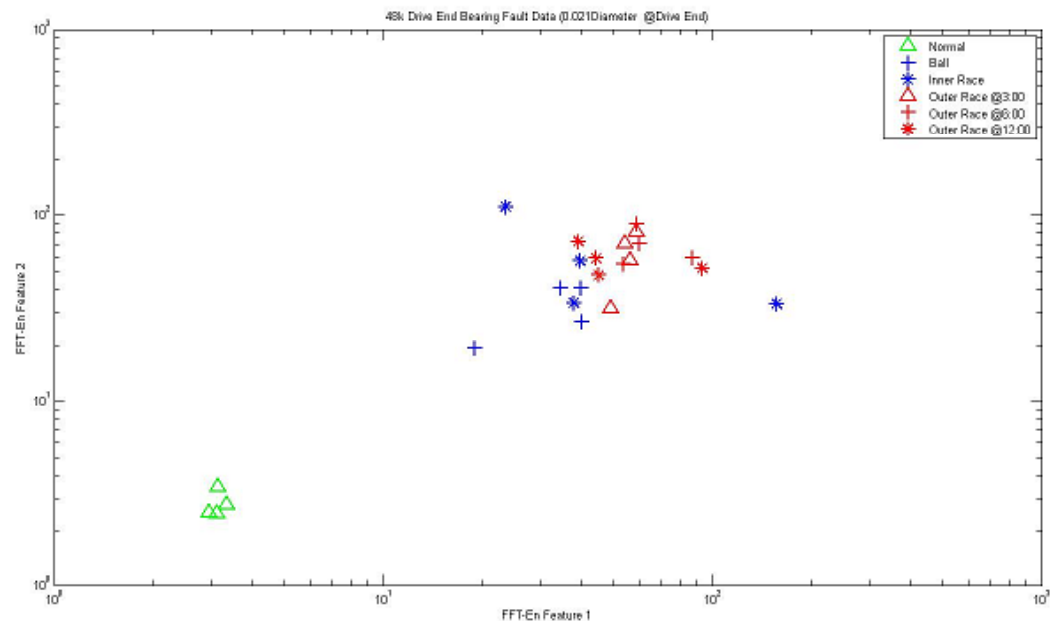


# Predictive Maintenance and Condition Monitoring of Marine Power Plant (3/4)

## Online Motor Fault Detection:



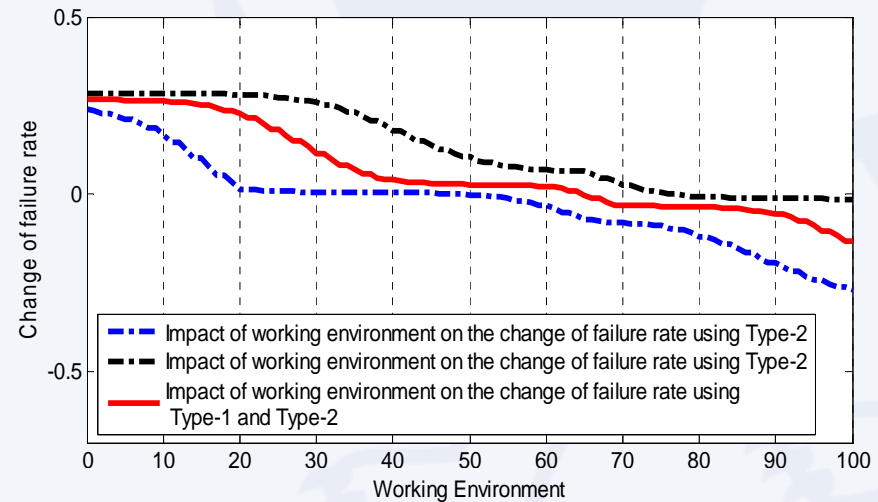
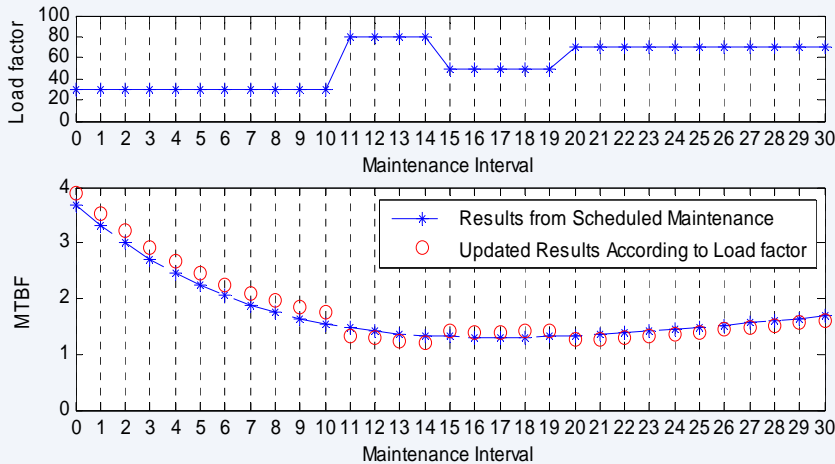
*Stator-current sensing*



*Vibration sensing*

# Predictive Maintenance and Condition Monitoring of Marine Power Plant (4/4)

## Interfacing Plant Operation with Maintenance Optimiser:



## LISTING OF COMPLETED/ ONGOING PROJECTS IN RELATED AREAS

S/N	PROJECT TITLE	Researchers	RESEARCH AREAS
1	Predictive Maintenance and Condition Monitoring of Marine Power Plant, Collaborators: MPA & APL	Chang Che Sau (ECE)	Energy Management
2	Intelligent Design, Operation and Virtual Testing of Offshore Power System, Collaborators: MPA & Keppel FLS	Chang Che Sau (ECE) Sanjib Kumar Panda (ECE)	Electric Propulsion/ Energy Management
3	Combustion and emissions control of internal combustion engines fueled by biofuels and novel blend fuels (Existing Project)	Yang Wenming (ME)	Energy Management
4	Renewable energy based high performance power electronic converters for green data centres	Sanjib Kumar Panda (ECE)	Energy Management

## LISTING OF COMPLETED/ ONGOING PROJECTS IN RELATED AREAS

S/N	PROJECT TITLE	Researchers	RESEARCH AREAS
5	Development of Smart Grid Platform with Distinguished Power and Communication Networks in the Laboratory Environment	Sanjib Kumar Panda (ECE)	Energy Management
6	Intelligent Wireless Sensor Network incorporating Energy Harvesting mechanism for Condition-Based-Maintenance of Electrical Energy Distribution System Equipment	Sanjib Kumar Panda (ECE)	Energy Management

## LISTING OF PROPOSED PROJECTS IN RELATED AREAS

S/N	PROJECT TITLE	LEAD IHL	PRINCIPAL INVESTIGATOR	RESEARCH AREAS
1	Energy and Emission Abatement of Green Ocean Liners	MI@NUS	Chang Che Sau	Energy Management
2	Understanding vessels movement and interactions	MI@NUS	Chang Che Sau	Energy Management
3	Fuel Consumption and Carbon Emission in the Port of Singapore	MI@NUS	Stephane Bressan	Energy Management
4	An Integrated Model for Green and Efficient Shipping	MI@NUS	Ng Szu Hui	Energy Management
5	Designing waste heat recovery system	MI@NUS	Koh Yee Kan	Energy Management
6	Development of the next generation dual fuel internal combustion engine	MI@NUS	Yang Wenming	Energy Management
7	Waste heat driven Adsorption desalination and Cooling	MI@NUS	NG Kim Choon	Energy management

## LISTING OF PROPOSED PROJECTS IN RELATED AREAS

S/N	PROJECT TITLE	LEAD IHL	PRINCIPAL INVESTIGATOR	RESEARCH AREAS
8	Optimal scheduling of generators and thruster motors to reduce the power consumption of marine vessel	MI@NUS	Sanjib Kumar Panda	Energy Management
9	Integrated Power & Electrical Propulsion System for Marine Vessels	MI@NUS	Sanjib Kumar Panda	Electric Propulsion

